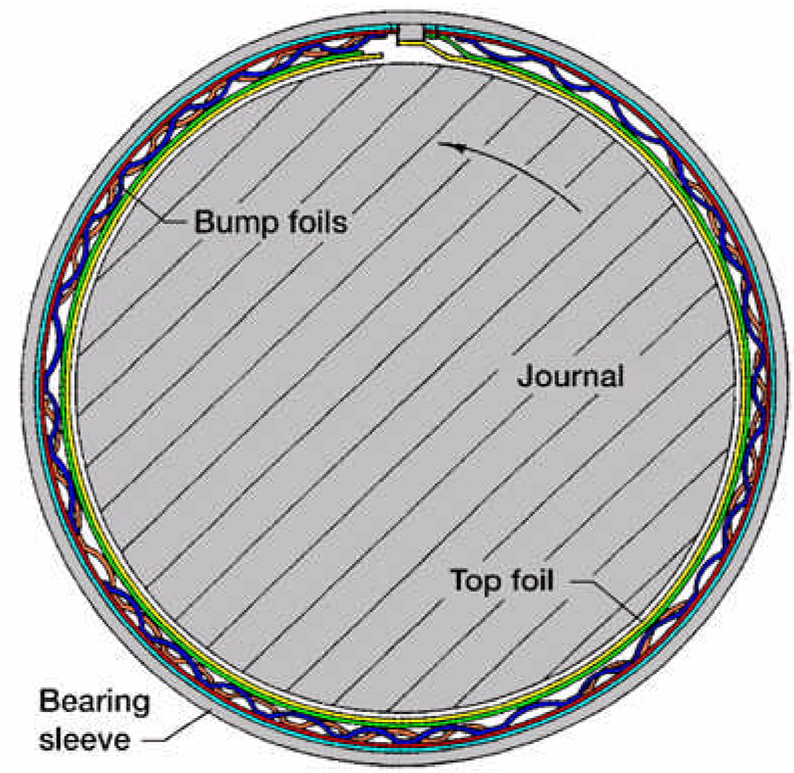
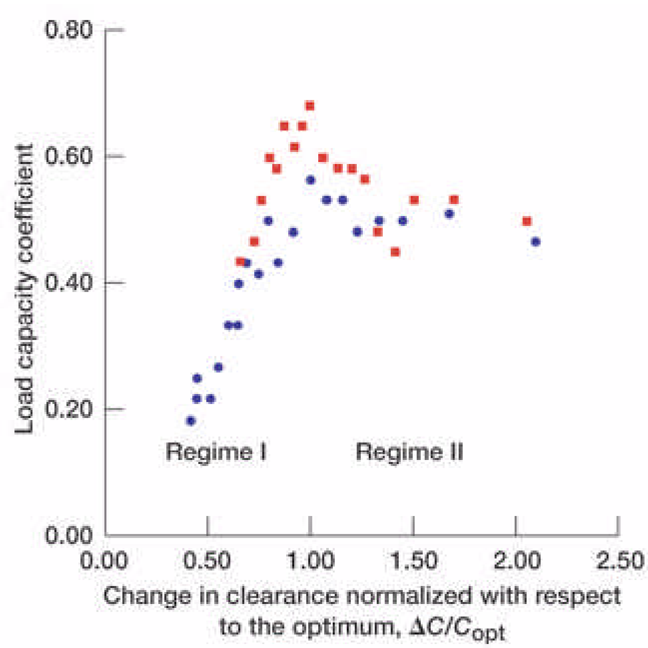
Radial Clearance Found To Play a Key Role in the Performance of Compliant Foil Air Bearings



Foil bearing cross section.



Bearing load capacity coefficient versus clearance.

Compliant foil air bearings are at the forefront of the Oil-Free turbomachinery revolution, which supports gas turbine engines with hydrodynamic bearings that use air instead of oil as the working fluid. These types of bearings have been around for almost 50 years and have found a home in several commercial applications, such as in air cycle machines, turbocompressors, and microturbines, but are now being aggressively pursued for use in small and midrange aircraft gas turbine engines. Benefits include higher operating speeds and temperatures, lower maintenance costs, and greater reliability. The Oil-Free Turbomachinery team at the NASA Glenn Research Center is working to foster the transition of Oil-Free technology into gas turbine engines by performing in-house experiments on foil air bearings in order to gain a greater insight into their complex operating principles.

A research program recently undertaken at Glenn focused on the concept of radial clearance and its influence on bearing performance. The tests were conducted on foil bearings with different radial clearances. As defined for a foil bearing, radial clearance is a measure of the small amount of shaft radial motion that is present from “play” that exists in the elastic support structure, such as between the top and bump foils and the bump foils and bearing shell (see the drawing). With an insufficient amount of radial clearance, the bearing imparts a high preload on the shaft, which when excessive, can reduce the load-carrying capability of the bearing. On the other hand, systems using foil bearings with excessive radial clearance may experience rotordynamic instabilities because of low bearing preload. Therefore, without a more thorough understanding of radial clearance, it is difficult to accurately predict the performance of a given bearing design.

The test program demonstrated that there is a direct correlation between radial clearance and the performance of foil air bearings. As shown in the graph, an optimum radial clearance exists that will maximize the amount of load that the bearing is capable of supporting. With respect to this optimum, two different performance regimes were observed that are a function of the amount of radial clearance. Tests showed that bearings with radial clearances below the optimum in regime I were susceptible to sudden seizure, a failure mode indicative of thermal runaway caused by high preload. The high preload is in response to an insufficient amount of radial clearance available to accommodate the thermal growth of the bearing and shaft. However, radial clearances greater than the optimum in regime II resulted in low bearing preloads that did not cause any heat-related problems, and the failure mode was due to fluid-film breakdown. In fact, bearings operating with radial clearances twice as much as the optimum suffered a decrease in the maximum load capacity of only about 20 percent.

Therefore, special attention has to be given to the range of operating conditions expected in the bearing/shaft system since changes in temperature, centrifugal, and hydrodynamic effects can all affect radial clearance. This enhanced understanding of foil air bearing behavior will greatly aid our efforts to transition Oil-Free technology to future aircraft engines.

Find out more about Oil-Free Turbomachinery research http://www.grc.nasa.gov/WWW/Oilfree/.

Bibliography

Radil; Kevin; Howard, Samuel; and Dykas, Brian: The Role of Radial Clearance on the Performance of Foil Air Bearings. NASA/TM--2002-211705, 2002.

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